DEVELOPING A MONITORING PLAN

Stages of Monitoring and Restoration

Monitoring is an integral part of the restoration process. Aspects of restoration monitoring should be considered throughout project design, construction, and implementation (Figure 2). Accurate gauging of the function of a restoration project is crucial not only to effective adaptive management of the project, but also to the success of future projects.

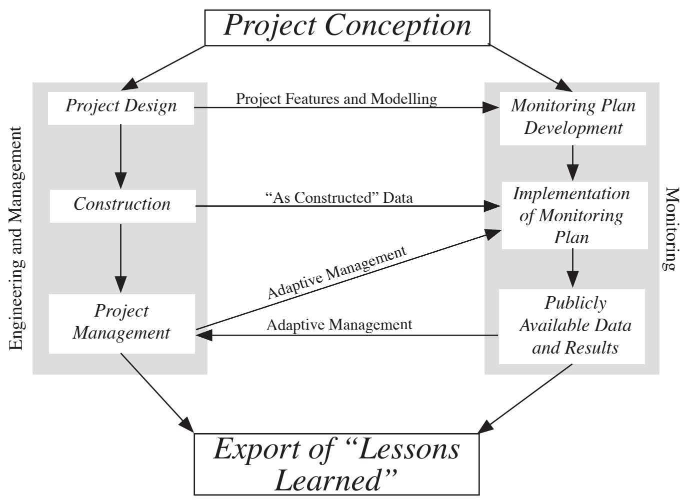

Figure 11. A flow diagram representing the process of developing, constructing, monitoring, and managing a coastal restoration project. The interaction of monitoring with other aspects of the process is emphasized. Illustration by Teresa McTigue, NOAA National Centers for Coastal Ocean Science.

Project Conception — Establish clearly defined project goals, objectives, and success criteria for a restoration project. These should be established not only on the basis of good science, but also on the goals and values of the local communities. These goals and objectives form the basis of the restoration monitoring plan. Before construction commences, it is necessary to establish how progress toward these goals and objectives will be measured.

Monitoring Plan Development — A restoration monitoring plan needs to be developed well before construction begins, as early as during the project design process. The steps for developing a monitoring plan are outlined in the following section of this document. Several important considerations should be made in the development of a monitoring plan. These include considering the impact of monitoring on the habitat, the selection of useful and appropriate reference sites, collecting baseline data, and the establishment of testable hypotheses.

In developing a restoration monitoring plan it is important to consider how to minimize the impact monitoring has on the habitat. For example, non-destructive sampling is recommended wherever and whenever possible. In addition, arrangements should be made for the clean up and removal of materials and equipment used to collect data. Materials (such as rebar) should never be left in the field upon completion of a monitoring project.

Reference sites against which the project area will be compared need to be identified. These sites can be of two forms: sites that possess attributes similar to the proposed restoration site and sites representing the condition to which the project area should optimally be restored. The type of reference site used depends on the goals of the restoration project and the availability of potential sites in the area. Multiple reference sites are highly recommended.

Comprehensive surveys of the project area and reference sites should be conducted to establish baseline environmental data. Information should also be obtained through analyses of archival materials and historical databases, when available. Field sampling and surveys should be done to address gaps in knowledge and to check the veracity of archival information. Modeling may be necessary, depending on the project in question. In obtaining baseline measurements, restoration practitioners should, depending on habitat type and surrounding conditions, consider characterizing and identifying species distribution and abundance; identifying habitats critical to resources of concern; calculating sediment budgets; determining local hydrographic regimes (including tidal and elevation data); document presence of invasive species and contaminants, and predicting possible changes in water quality and channel morphology. It also is important to identify watershed input-related problems that may impact not only the success of restoration within the estuary, but also the restoration practitioners' ability to develop appropriate water quality parameters. This descriptive information is critical to the development of the restoration monitoring plan.

Habitat characteristics to be monitored should be determined based on the goals for the project. It is important that the restoration monitoring plan establish testable hypotheses for each restoration goal. For each set of hypotheses, the plan should address data collection, recording, and analysis procedures. Valid statistical sampling and analyses should be established for each habitat characteristic to be monitored. Metadata should be reported in a format compatible with the NOAA ERA database. Timing of sampling should also be considered. Structural characteristics of the restored area should be monitored at the greatest frequency for several years immediately after construction. Functional characteristics[4], however, should be monitored later, as the system matures and the function in question has had time to become adequately established.

Implementation of Monitoring Plan — The three phases a practitioner progresses through when implementing a monitoring plan are pre-construction monitoring, monitoring during construction, and post-construction monitoring.

> *Pre-construction monitoring* — It is critical to begin monitoring both the project area and reference sites well before project construction begins. Pre-construction monitoring coupled with information used in the characterization of the site will give an indication of the current variability in a parameter. This variability can be related to short-term events, such as storms, or can result from seasonal or inter-annual patterns. While it is often difficult for those involved with monitoring to influence the construction schedule for a project, a pre-construction sampling period of at least a year is highly recommended. This monitoring should be conducted according to the restoration monitoring plan and the data should be collected and analyzed in a statistically valid manner. Pre-construction data and results should be made available to project engineers and managers to help them in the design, implementation, and scheduling of the project.
>
> *Monitoring during construction* — Upon completion of baseline data collection and restoration monitoring plan development, restoration construction can commence according to project design and specifications. Monitoring should be implemented during construction to ensure that proper design specifications are met.

[4]*Structural and functional characteristics for each habitat type are listed in Appendix I of this volume and receive extensive treatment within Volume Two: Tools for Monitoring Coastal Habitats*

Post-construction monitoring — Post-construction monitoring should be done according to the restoration monitoring plan, including the collection and analysis of data in a statistically valid manner. Data should be made available to project managers and engineers in a timely manner, as per the monitoring plan, to allow for adaptive management of the restoration project and associated programs.

Measuring progress in the development of habitat characteristics and associated community structure as well as working toward habitat stability and desired ecological and socioeconomic endpoints is a means of evaluating success of a restoration effort. Deviations from the expected trajectory may be considered justification for potential mid-course corrections.

Export of data, results, and "lessons learned" — To be useful, monitoring data, results, and "lessons learned" have to be shared. Information resulting from a well-designed and conducted monitoring program supports the timely and successful management of on-going restoration projects. Project managers can use results in adaptive management to make mid-course corrections in the operation of project features. Additionally, monitoring information regarding the performance of both a project overall and its constituent features is highly useful to individuals designing current and future projects with similar features and goals or in similar habitats. Monitoring data, results, and a discussion of lessons learned should be made available through a publicly available source such as a well-advertised web page. A goal of this process should be the long-term reduction of monitoring costs through implementation of increasingly efficient approaches.

Figure 12. Using a canoe to sample for adult insects in a marsh on the Black River in New York along Lake Ontario. Photo courtesy of Doug Wilcox, United States Geological Survey.

Figure 13. Fyke net sampling along Marshy Creek North, Knapps Narrow, Maryland. Photo courtesy of Dave Meyer, NOAA Restoration Center. Publication of the NOAA Central Library. http://www.photolib.noaa.gov/habrest/r00psc01.htm

The Process of Developing a Monitoring Plan

When developing a scientifically based and statistically valid restoration monitoring plan, a logical process should be followed that considers a sequence of twelve steps:

1. Identify the goals of the project established in the project planning documents and any applicable watershed restoration plan.
2. Identify the type of restoration project and collect information on the monitoring of similar projects.
3. Identify and describe the extent of the habitats within the project area.
4. Define basic structural, functional, and socioeconomic characteristics.
5. Consult experts.
6. Determine hypotheses to be tested in determining progress toward project goals.
7. Collect historical data and indications of trends and causes of decline.
8. Identify reference sites.
9. Identify monitoring time span.
10. Identify monitoring techniques.
11. Design a monitoring review and revision process that complies with the requirements of the restoration program.
12. Develop a cost estimate for implementation of the monitoring plan and compare to available funds.

1. Identify the goals of the project established in the project planning documents and any applicable watershed restoration plan – All restoration projects have identified goals. The monitoring of a restoration project should be designed to determine if the project is functioning as planned and to test progress toward the project goals. These goals are usually identified in the project proposal and design documents and should have been developed through discussions among scientists, socioeconomists, and the affected community. In addition to project goals, regional restoration goals need to be considered to determine the contribution the project in question is making to the restoration of the bay or watershed as a whole. Steps 2 through 12 of this process of developing a monitoring plan should be reflective of the goals of the restoration project.

2. Identify the type of restoration project and collect information on the monitoring of similar projects – Coastal restoration projects tend to fall into a series of broad categories including, but not limited to hydrologic restoration, shoreline stabilization, and vegetative planting. While techniques can be new and innovative, consideration of approaches taken by others conducting restoration monitoring of projects within the same category can be exceptionally helpful in the development and implementation of a successful monitoring plan.

3. Identify and describe the extent of the habitats within the project area – It is critical that the area to be affected by a restoration project be determined and the habitats within that area be identified and mapped. The areal extent of habitat will contribute to the baseline for assessment of habitat gains toward the ERA goal of one million acres by 2010. The acreage counted toward this goal will be those acres over which monitoring can demonstrate improved function[5]. This information can drive the selection of variables to be monitored and provides basic information to be used to determine historical patterns of habitat change, as well as the impacts of the project.

4. Define basic structural and functional characteristics for those habitat types – Each coastal habitat has structural components that define that habitat. The functional components are the processes going on within and between habitats and their structural components. The ultimate goal of any restoration action should be to return functions and not simply build structure. Understanding the structure and function of a habitat allows an understanding of the fundamental ecology of the system and selection of those parameters most relevant to the goals of the project. In selecting characteristics for monitoring, both structural and functional characteristics should be included and should be integrators of several factors. For example, the number and type of birds on a beach are structural parameters. The type may indicate food resources; likewise the absence of normal bird species may be indicative of the absence of their preferred food. The length of time a species spends there may be a function of availability of food, as well as the type of food available. As noted in item 3 above, improved function is a part of the metric that will be used to determine progress toward meeting the overall goal of the Estuary Restoration Act of 2000. Indications of function should be monitored.

Though there is a set of structural and functional characteristics usually measured in a habitat, each restoration monitoring plan generally will be unique because it should provide information to support the assessment of the project goals. The information provided should be used as a starting point and should be augmented based on local conditions and the goals of both the project and the large-scale restoration effort.

[5]*Personal communication, August 13, 2003, Mary Baker, NOAA Office of Response and Restoration.*

The first matrix in Appendix II lists the physical and biological characteristics for habitats that have a high probability of being monitored as a part of coastal restoration project. Within each list, some characteristics should be monitored in any restoration project constructed in that habitat type, regardless of the specific goals. Other characteristics can also be monitored, depending on the goals of the project or watershed level restoration effort. The second and third matrices in Appendix II then assist the restoration practitioner in determining the parameters appropriate for monitoring those characteristics in the appropriate habitat.

5. Consult experts – Individuals or groups developing restoration monitoring plans should never work in isolation. It is imperative that a statistician be consulted early in the process. Additionally, ecologists, hydrologists, botanists, economists, or other scientists with appropriate fields of specialization should review the plan and provide advice on sampling approaches. It would be valuable, as well, to contact resource managers conducting similar monitoring for input as to lessons learned. In *Volume Two: Tools for Monitoring Coastal Habitats*, lists of experts who have agreed to make themselves available for questions will be provided by habitat.

6. Determine hypotheses to be tested in determining progress toward project goals – For each project goal and applicable regional restoration goal, at least one set of testable hypotheses should be created. A set of hypotheses includes a null hypothesis that describes a condition of no change or difference (i.e., salinities in the project area before and after implementation will be equal) and at least one alternate hypothesis that describes a potential change (i.e., salinity within the project area will decrease after the implementation of the project). A statistician should be involved with the establishment of these hypotheses. Further discussion of null and alternate hypotheses can be found in any introductory statistical textbook.

7. Collect historical data and indications of trends and causes of decline – Historical data, if available and of reliable quality, should be obtained for use in determining long-term trends in habitat change. The quality of these data needs to be assessed early in the project design process. Historical information can also provide insight into how the habitat functioned prior to degradation and provide a general baseline of ecological function.

8. Identify reference sites – *Appropriately* selected reference sites allow for the evaluation of progress toward restoration endpoints and the accurate assessment project performance. Two types of reference sites can be used: natural or disturbed. Reference sites reflecting natural conditions serve as indicators of endpoints for the restoration effort. Disturbed reference sites provide information on the rate of recovery, serving as an indication of potential conditions in the project area had the project not been constructed. Using several reference sites forms a basis to judge the progress the restored habitat makes in approaching the structural and functional status of a comparable natural system (Weinstein et al. 1997). The more reference sites used, the more valid the comparison. Progress toward restoration goals can also be evaluated by comparing to reference conditions. The sampling of reference sites should be coordinated with the sampling conducted in the project area.

In addition to reference sites, extensive pre-construction monitoring can be used to provide reference conditions against which the project area can be compared. Analysis of pre- and post-construction conditions within the project area can be valuable, particularly when paired with the use of reference sites. If no site is available that adequately parallels the current condition of a project area, reference conditions can be used as the sole source of comparison for the project area. Reference conditions, however, are limited in that they do not allow for natural variability in parameters from year to year. Factors beyond the scope of the project, such as a drought or severe storm, can cause significant impacts to the area being restored. Reference sites would reflect this variability when reference conditions probably would not.

Restoration projects often attempt to recreate habitat conditions that were historically present in an area. In situations where records of historic plant and animal species and physical conditions are available, those records may be used as the reference condition to which a restoration project may be compared. Detailed records of the plant and animal species that inhabited a particular coastal habitat, however, are rarely available. In these situations or where restoration of historical conditions is not possible, restoration sites need to be compared to existing sites. Reference sites may be chosen in a variety of manners depending on vegetation type, geomorphology, hydrodynamics, degree of degradation, habitat or hydrologic functions, or landscape-scale characteristics. A review of approaches used in the selection of appropriate monitoring reference sites and conditions is available in the *Volume Two: Tools for Monitoring Coastal Habitats*.

9. Identify the monitoring time span – The restoration monitoring plan should include a detailed schedule of what characteristics are to be monitored when and for how long. All methods used to monitor the restoration project after implementation need to be identified. This helps ensure that baseline and reference site data will be comparable to data collected during monitoring. The monitoring time span for a restoration project is composed of three factors: seasonality, frequency, and duration. Each of these depends on the specific goals of the project and the performance criteria selected for monitoring.

Seasonality

Vegetation communities; fish, wildlife, and migratory bird use; hydrologic patterns; water chemistry; and other structural and functional aspects of coastal habitats often change over various time scales. Tidal patterns follow a lunar cycle, migratory birds may pass through an area only once or twice a year, flooding typically follows seasonal precipitation patterns, herbaceous plants can be present (even dominant) for only a short portion of the growing season, and fish and amphibians may use an area for only a few weeks for spawning or as a nursery area for their young. Each characteristic chosen as part of a monitoring plan will have its own seasonal requirements that need to be addressed and incorporated into the monitoring schedule before data collection in the field. Even then, monitoring schedules or parameters may need to be changed after initial sampling. For example, the determination of migratory bird use of restored or reference areas might not be physically possible with available equipment due to seasonal flooding. A change in the chosen metric, the season of sampling, or the purchase of different equipment may be necessary to complete sampling as planned.

Ideally, both reference and restored areas would be sampled each time sampling is done. This would ensure any natural variation these sites experience from year to year is characterized and not attributed to the restoration effort. Resources, however, may not provide for such a rigorous sampling schedule. In these cases, sampling of specific parameters in reference areas should take place during the same time of year as sampling in restored areas. For example, since herbaceous plant communities change throughout the year, sampling in restored and reference sites needs to occur during the same season (preferably the same month). This is true also for sampling of invertebrates, fish, migratory birds, water chemistry, algae, and zooplankton.

Figure 14. Freshwater marsh in spring.

Figure 15. Freshwater marsh in late summer.

Figures 14 (spring) and 15 (late summer) are photographs taken from different vantage points of the same marsh (yellow arrow marks landmark trees in the background) in southeastern Michigan. These photos illustrate the importance of accounting for seasonality in restoration monitoring. Monitoring projects that seek to compare restored vegetation communities over time or compare reference areas to restored sites should take measurements as close to the same time each year as possible to ensure comparability of data. Photos courtesy of David Merkey, NOAA Great Lakes Environmental Research Lab.

Frequency

The frequency of monitoring and the type of characteristics measured change over time as the restoration project develops, both structurally and functionally. Three different restoration monitoring phases are identified and described: post-implementation, intermediate, and long-term. The emphasis on which types of characteristics are monitored changes as the system matures.

Post-implementation monitoring occurs over the first (and sometimes second) year after project implementation. The focus is on structural, physical-chemical characteristics, and other habitat parameters directly manipulated as part of the restoration. Immediately after construction, the site should be monitored weekly to check for erosion and sedimentation and to ensure any water control structures or irrigation equipment are functioning properly. Once these components are functioning properly, monitoring can be scaled back to a monthly schedule for the rest of the post-implementation phase (Clewell and Lea 1990). Weekly monitoring is done to gauge early progress of the restoration and identify errors resulting from poor site preparation so any potential problems may be identified and corrected quickly. Examples of post-implementation monitoring are as follows:

- Percent seedling survival
- Plant cover and composition
- Density and composition of organisms living on oyster reefs
- Sediment grain size
- Erosion rates
- Sediment and water column salinity

The hydrology of the system should also initially be monitored closely to ensure it is acting according to plan. As individual structural or functional characteristics begin to meet project goals, monitoring can be done annually or every few years to ensure that the system is still functioning according to plan.

During intermediate years (e.g., 2 - 4 years after implementation), the focus of monitoring often shifts from basic structural components to a combination of both structural and functional characteristics where possible. Functional measures integrate a variety of structural characteristics and provide information on ecological community interactions and habitat contribution. For example, once the restoration effort has good seedling survival and plant cover and composition, these measurements are at first scaled back from monthly to seasonal or annual sampling times and eventually replaced with measures of growth, biomass production, or wildlife use. For some slow growing habitats such as reefs or forests, this shift in monitoring focus and frequency takes longer. Allen et al. (2001) recommends waiting 3 - 5 years after planting to even begin assessing seedling survival and stocking rates in restoration of forested systems.

The long-term phase of monitoring begins once the restoration project has reached, or is on a definite trajectory toward achieving, its structural and functional goals. During long-term monitoring, measurements should be taken annually or every few years, depending on the measurement in question and the goals of the project. Functional or process oriented studies should continue at a statistically supported frequency and on a schedule required to address the hypotheses in question.

Duration

The span over which restoration monitoring should be conducted generally depends on processes to be evaluated and the habitat to be restored. Suggested time frames published in the literature range anywhere between three to fifty years (D'Avanzo 1990; Zedler 1995; Bradshaw 1996; Mitsch and Wilson 1996; Simenstad and Thom 1996; Fonseca et al. 1998; USACE-WES 1999) depending on the objective of the restoration project.

Project monitoring should cover a time period appropriate to statistically evaluate change in the characteristic in question. If a restoration project entails only subtle changes in a degraded habitat, the restoration can achieve its functional goals in as little as three years (Weller 1995). If, however, a more complex restoration is attempted or the entire system requires reestablishment, functional goals may not be achieved for several decades (Mitsch and Wilson 1996). The restored system needs time to develop a range of ecological functions and human values. The monitoring should be long enough to accurately assess this process. Whenever possible, it is recommended that monitoring continue until the system is self-sustaining.

At an absolute minimum, restoration monitoring should be done for at least five years following the completion of project construction (Clewell and Lea 1990). In most habitats, however, the time period over which monitoring should be conducted will be substantially longer (Block et al. 2001; Conner et al. 2000; Kellogg and Bridgham 2002; Mitsch and Wilson 1996; Simenstad and Thom 1996; Streever 1999).

Figure 16. Sediments at Port Sheldon drowned-river-mouth wetland in the Great Lakes area exposed by low lake levels in 1999. Photo courtesy of Doug Wilcox, United States Geological Survey. http://www.glsc.usgs.gov/science/wetlands/waterlevels.htm

10. Identify monitoring techniques - In most cases, there are multiple statistically defensible approaches to restoration monitoring any given habitat. After extensive review of monitoring programs and plans of similar projects, work in similar habitat types, or plans that overlap geographically with the project in question, monitoring planners should outline the project design and rationale, sampling frequency, and characteristics of interest and link them to project goals. The sampling methods and approach should be described in detail for review and should be based on sound statistical sampling design. Additionally, the number of sampling stations, location of those stations, and the number of samples collected are critical decisions that impact the power of the analyses. It is strongly recommended that a statistician be consulted. Whenever possible, the sampling methods used should be non-destructive.

Figure 17. Port Shelton in 2001 after seedbank germination and colonization of exposed substrate by wet meadow vegetation. Photo courtesy of Doug Wilcox, United States Geological Survey. http://www.glsc.usgs.gov/science/wetlands/waterlevels.htm

Experimental studies can be performed onsite in conjunction with restoration and monitoring. Restoration science will continue to be refined through carefully planned and executed experiments and peer-reviewed manuscripts. Controlled, replicated field experiments can illustrate successes and failures in restoration methodologies and techniques. Both successes and failures need to be documented and published to further restoration science. In many instances, these experimental studies could be built into select restoration projects through dedicated funds.

11. Design a monitoring review and revision process that complies with the requirements of the restoration program – Monitoring data should be made available to restoration practitioners and decision makers, both those working on the project in question and those who could apply the lessons learned, to maximize the usefulness of the data. Monitoring reports need to include careful assessment, review, analysis, and synthesis of results in addition to presentation of results and simple statistics. The lack of synthesis is a major shortcoming of some restoration monitoring programs; information, data and concepts are not brought together in a way that is easily understood by a wide audience (M. Posey, University of North Carolina - Wilmington, pers. comm.).

There should be a reporting system and schedule that makes data and results interpretation available in a timely manner and in a useful format. A well-designed and easily accessible reporting system facilitates adaptive management at both the project and watershed or bay system level. A Quality Assurance/Quality Control (QA/QC) plan should be developed that outlines the means of data collection, formatting, storage, and public accessibility. Examples of QA/QC documents can be found under each habitat of *Volume Two: Tools for Monitoring Coastal Habitats*.

Managers should be held accountable for complying with this plan. Restoration monitoring data are most valuable when consistent with or easily convertible to standard data formats already in general use. This allows the results of the monitoring effort to be analyzed and applied by people designing or evaluating both this and other restoration projects. Additionally, it allows project and monitoring managers to assess the monitoring plan itself. If, despite a thorough planning process, a monitoring effort is not adequately assessing progress toward restoration goals, the monitoring plan should be modified.

For projects funded under the ERA, information on habitat extent must be presented in acres to allow for assessment of progress toward the Act's goal of restoring one million acres of coastal habitat. For other restoration monitoring variables, data should be collected in the format that is the established standard for that variable and technique. In *Volume Two: Tools for Monitoring Coastal Habitats,* monitoring techniques manuals are included for each habitat considered. Additionally, a database is presented that reviews coastal restoration monitoring programs. Links are provided to these programs that provide access to manuals, QA/QC documents, and standards established for these programs.

12. Develop a cost estimate for implementation of the restoration monitoring plan and compare to available funds – A restoration monitoring plan should provide for sufficient personnel, funding, and authority to provide all easements, rights-of-way, maintenance, and monitoring. The cost of monitoring varies, depending on techniques used, frequency of sampling, and the length of time over which monitoring is conducted. In some cases, the amount of money available from a project budget for monitoring is determined by the authorizing legislation or by agreement among participating parties. In all cases, determining the percentage of a restoration budget to be allocated to monitoring is a balancing act where costs need to be built in up front. One should dedicate enough resources to monitoring so the assessment of project impacts and progress toward goals is statistically and scientifically valid. The monitoring, though, should not eclipse the restoration work. Sample costs associated with coastal restoration monitoring are provided in *Volume Two: Tools for Monitoring Coastal Habitats*.

Writing a Restoration Monitoring Plan

A restoration monitoring plan should contain certain basic information that allows managers, scientists, and statisticians participating in the monitoring over the long term run of the project to understand what is to be done, when it is to be done, and why it was included in the plan. These critical plan elements are as follows:

Background Material

- Description of the project area, including habitat types and acreage, and estuary/ watershed
- Discussion of the habitat trends and causes of loss or decline in the area
- Review of the project, including components and the time table

Project Goals and Objectives

- Goals and objectives defined for the project
- Goals and objectives of the regional restoration plan that are relevant to this project

Monitoring Components

- Listing of habitat characteristics or functions to be monitored in the assessment of progress toward project and regional restoration goals
- Statement of the null and alternative hypotheses to be tested as a means of assessing progress toward project and regional restoration goals
- Discussion of the reference sites to be used, including location and the methods used in and justification for selection of the sites
- Detailing of pre-construction sampling and data mining to be used in establishing historical and baseline conditions, including techniques, frequency, and sampling QA/QC
- Detailed plan for sampling during and after construction, including techniques, frequency, sampling QA/QC, and provisions for adaptive management
- Detailed discussion of statistical analysis to be employed in hypothesis testing
- Detailed plan for data handling, storage, and accessibility (data QA/QC procedures)
- Report preparation and distribution plan
- Provision for review of the effectiveness and efficiency of the monitoring plan after implementation

Projected Monitoring Budget

- Estimates of the costs associated with the implementation of the monitoring provided by category of cost and year

Participants and Contact Information

- Contact information for the restoration project manager and monitoring plan manager
- List of the individuals involved in the development and review of the plan

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